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FOREST MANAGEMENT RESEARCH

ENGELMANN SPRUCE-SUBALPINE FIR, LODGEPOLE PINE,

AND ASPEN FOREST TYPES

at the

FORT COLLINS RESEARCH CENTER

Rocky Mountain Forest and Range Experiment Station

(A Project Analysis and Working Plan)

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PREPARED:

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Director

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INTRODUCTION

The Rocky Mountains contain the last extensive areas of virgin timber in the United States. In the central Rockies, below the crown of alpine tundra and snowfields and above the ponderosa pine, are found forests of Engelmann spruce-subalpine fir, lodgepole pine, and aspen. In this last frontier of predominately virgin timber lies the future of a growing population that looks to the Rockies for water, wood, recreation, and mineral resources.

The commercial forests of the central Rockies are contained within two extensive climatic belts or zones. The lower belt, or montane life zone, is characteristically a region of cutover, open ponderosa pine, intermixed with Douglas-fir. Altitudinally, this forest association is found between 6,000 and 9,000 feet. Throughout the montane zone, but particularly at the higher elevations and cool aspects, moist and dry aspen groves and lodgepole pine-Douglas-fir forests are found.

Above the montane zone is the region of dense-growth Engelmann spruce-subalpine fir -- the subalpine zone. It extends to timberline at 11,500 to 12,000 feet, depending upon geographical location,

exposure, and aspect. This predominately virgin forest receives the heaviest snowfall of any in the mountains. Because of the heavy forest and high elevations, the snow remains late into the spring and sometimes well into the summer. The abundance of moisture makes, particularly, the upper portion of this zone the most luxuriant of all in vegetation. Near-continuous spruce-fir forests are interrupted here and there by lakes and marshes, and contain pure or nearly pure lodgepole pine stands on lower slopes, south-facing exposures, or on sites with a fire history. Extensive stands of aspen may also be found here. White fir, corkbark fir, limber pine, whitebark pine, bristlecone pine, and blue spruce are commonly found within this zone, but these occur less frequently than the other species.

The distribution of the forest types of Engelmann spruce-subalpine fir, lodgepole pine, and aspen forest types is shown in Figure 1. This area, bound within the altitudinal band of 8,000 to 12,000 feet, contains approximately 14.5 million acres. Although no accurate figures are yet available on areas of individual forest types, they may be estimated as follows:

Engelmann spruce-subalpine fir	7.0	million acres
Lodgepole pine	5.5	" "
Aspen	2.0	" "
Total	[1] 14.5	" "

[1] These areas represent total forest land. The areas of commercial forest are much less. (Extension of Tables 5 and 6 of Region 2 T.R.R. Basic Tables, October 27, 1955.)

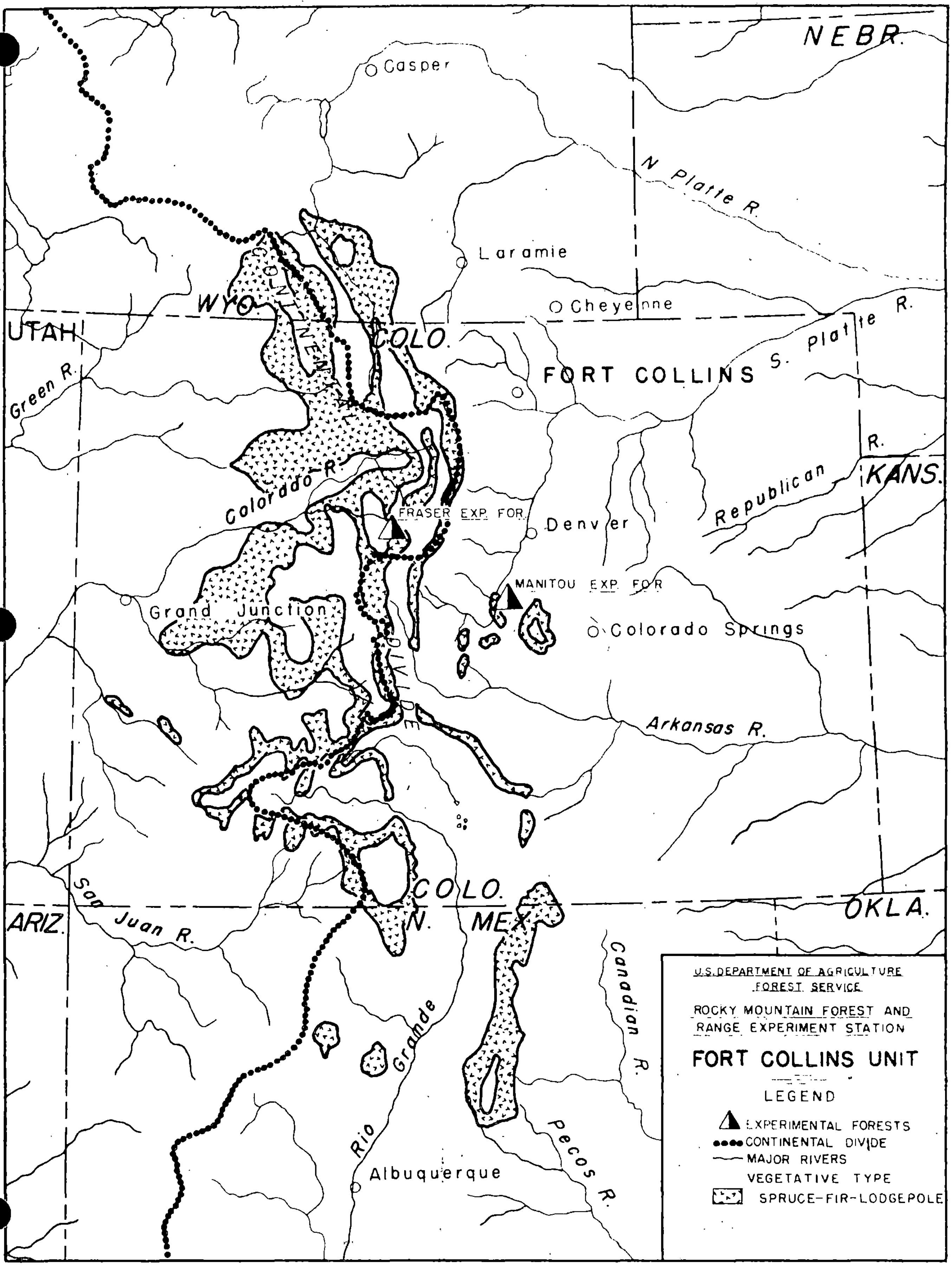

Figure 1.--Distribution of Engelmann spruce-subalpine fir, lodgepole pine and aspen forest types.

Map #5

Besides having no exact figures on the total acreages of the four major species found in the subalpine zone, there are estimated figures only for commercial acreages and net volumes. The Forest Survey has not yet completed its work in Colorado and Wyoming, nor begun work in New Mexico. The following tabulation[2] for all of Colorado, and for that part of Wyoming east of the Continental Divide, gives approximate extent of commercial forest lands and net volumes of live sawtimber:

	Acres	Board-feet (Millions)
Spruce-fir	3,223,000	[3] 16,889
Lodgepole pine	3,225,000	8,064
Aspen	[4] 1,030,000	1,994

In addition, T.R.R. figures listed 1,436 million board-feet of salvable dead sawtimber, most of which was dead Engelmann spruce.

On any given watershed, all three forest types are likely to be found. (Fig. 2) On north and east slopes, the spruce-fir type usually extends throughout the elevational range of the zone. On south slopes, lodgepole pine may cover the complete range of elevation. Aspen may occur on any aspect, but is found most abundantly at elevations below 10,500 feet.

2/ From Tables 6 and 10B, Region 2 T.R.R. Basic Table, October 27, 1955.

3/ Engelmann spruce, other spruces, and all true firs.

4/ Mostly aspen.

Figure 2.--Engelmann spruce-subalpine fir, lodgepole pine, and aspen stands on a single watershed.

Climate and Physiography

The climate is characterized by a moderate to light precipitation, a dry atmosphere, short-growing season, heavy snows in winter, and strong winds at higher elevations. Annual precipitation varies from 20-40 inches, much of which falls as snow. Cumulative snow depth may be as little as 3 feet to as much as 30 feet. The growing season at the lower limits may be as long as 4 months; at the upper limits, as short as 60 days. Average annual temperatures are 30- to 35-degrees Fahrenheit and near timberline, frost occurs frequently, even during the summer.

Two general physiographic provinces are found within the subalpine zone -- the high mesas of the Colorado Plateaus and the several continuous mountain ranges that make up the central Rockies. The Colorado Plateaus consist of the White River Plateau, Grand Mesa, Book Plateau, Uncompahgre Plateau, and the Dolores Plateau, named in order from north to south. The major high mountain chains are the Front Range, Medicine Bow Range, Park Range, Saguache Mountains, Sangre de Cristo Range, and the San Juan Mountains. (Fig. 3)

The top surface of the plateaus gently undulate, reaching elevations over 10,000 feet. Broken, patch-like, and continuous stands of spruce-fir are found growing on the plateaus (Fig. 4), intermingled with or surrounded by groups or forests of aspen. The steep, precipitous sides of many of the mesas support either spruce-fir or lodgepole pine, depending upon exposure and fire history.

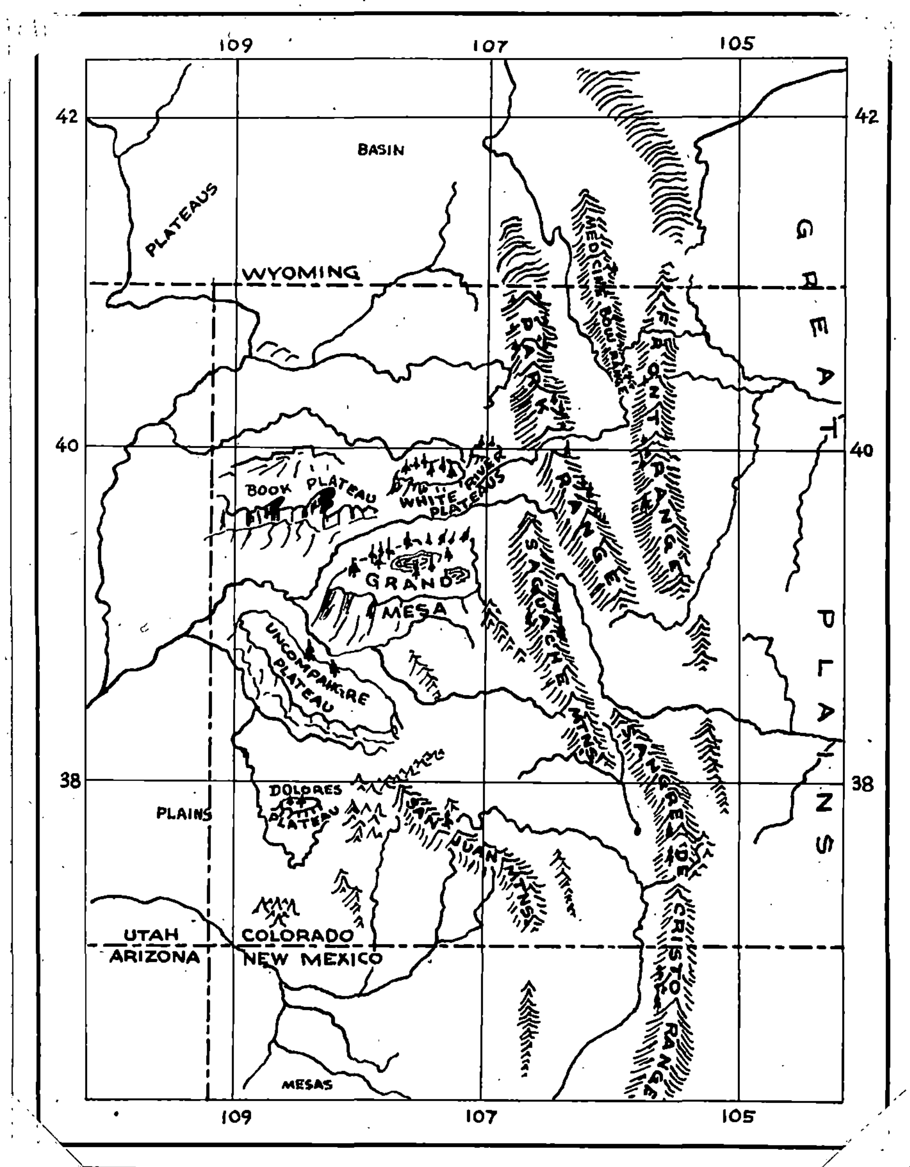

Figure 3.--Schematic map of important plateaus and mountain ranges in the Engelmann spruce-subalpine fir, lodgepole pine, and aspen forest zone.

Figure 4.--Grand Mesa Engelmann spruce-subalpine fir forest.

The topography of the subalpine zone of the mountain chains is rugged with steep slopes (Fig. 5) and many narrow, V-shaped valleys. This results in a number of micro-climatic variations associated with solar radiation differences. At this latitude, a 70-degree, south-facing slope receives, during spring and summer, the same intensity of sunlight as does a horizontal surface at the equator, and the possible hours of sunshine are the same. For this reason, south-facing slopes are less favorable to spruce-fir than for lodgepole pine. Over the same period, a similar, but north-facing slopes, receives sunlight at the same intensity as a horizontal surface in northern Alaska and for much less of each day. These conditions favor spruce-fir. Throughout the limits of the subalpine zone of the mountain ranges, spruce-fir is normally found on cool, north- and east-facing slopes at lower and middle elevations and on all slopes at higher elevations. Lodgepole pine grows on southern and western exposures at lower and middle elevations. (Fig. 6)

While most slopes within the subalpine zone are less than 70-degrees, there are many that are nearly as steep, so the preceding discussion illustrates potential micro-climatic variation and resulting vegetation. Spruce-fir always grows on cooler slopes, except where they have been recently burned over. Lodgepole pine may occur as a temporary forest type on these areas.

Figure 5.--High elevation spruce-fir forest in Cameron Pass, Roosevelt National Forest.

Figure 6.--Southwest-facing slope (right middle) with lodgepole pine extending to ridge top. Northeast and east facing slopes with spruce-fir (left middle).

Geology and Soils

There is little information available on the classification of soils found where subalpine vegetation grows. Many different kinds of soils, varying from shallow, stoney, well-drained gravels and sands, to deep, heavy, moderately drained silt and clay loams are found here. Generally, throughout the range, good spruce-fir sites are found on the high plateaus, benches, and gentle slopes where soils are developed from basaltic, andesitic, and rhyolitic rock; and sedimentary limestones and sandstones. These soils are fine-to medium-textured sand and silt loams, moderately deep, well-drained with good water-holding capacity. Soil acidity ranges from moderately acid to highly acid where a true podsol has formed.

Good spruce-fir sites also are found on lower valley slopes and flood plains. The soils are alluvial, developed from a wide range of parent materials. The nearness of the water table to the surface is more important than the physical properties of the soil in determining tree growth on these sites. Engelmann spruce and subalpine fir do not make good growth on heavy clay surface soils, or on saturated soils. Subalpine fir is less exacting in its soil and moisture requirements than is Engelmann spruce. It is frequently found growing on soils too wet or too dry for spruce.

Lodgepole pine is not exacting in its soil requirements and grows on a wide variety of soils. Good stands are found on soils of granitic, shale, or sandstone origin. Extensive stands also occur on

soils derived from coarse-grained lavas. Soils derived from limestone or fine-grained, igneous rocks do not support good stands. The former are too dry, while the latter break down into clays that are poorly drained.

Aspen is found growing on soils suitable for either spruce-fir or lodgepole pine. It is often the first tree to establish itself on fire-denuded and clear-cut forest lands. Where seed source of the former forest of spruce, fir, or pine survive, aspen is ultimately crowded out. (Fig. 7) (See discussion of soils in watershed management research discussion.)

IMPORTANCE OF AREA

Cutting of timber began soon after the midpoint of the nineteenth century. At first, cutting was only done to supply wood products and fuel to locally booming mining industries and to railroads pushing their way to the Pacific Coast. In later years, near the turn of the century, some lumber was produced for shipment outside the region. However, most of the cutting was still for mine props, telephone poles, and railroad ties. The annual cut of lumber in the central Rockies now is about 200 million board-feet. More than half of this comes from the forests above 8,000 feet and increased production is expected. The lumber is used both locally and in adjacent states to help satisfy the appetite of a booming building industry.

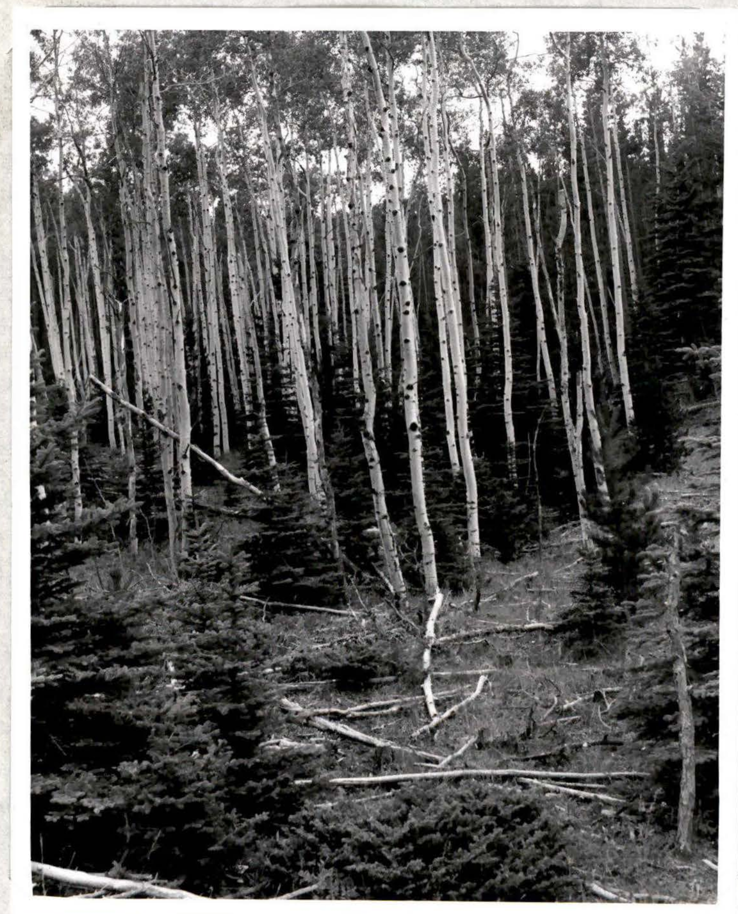

Figure 7.--Spruce-fir coming in with an overstory of aspen following logging.

Demands for wood pulp products have sharpened interest in the large, untapped pulp resources in the Rockies. Spruce, fir, pine, and aspen are all good pulping species. These species are more adapted to pulpwood than sawtimber production because of slow growth and small size. Large volumes are contained in timber that is mature before it reaches sawtimber size. In addition, we have a supply of more than 6 billion feet of standing beetle-killed spruce (Fig. 8) which will not make good lumber, but will be good for pulp (Fig. 9) for at least 25 or 30 more years.

Demands for ties, posts, and poles remain to be satisfied. Subalpine fir and lodgepole pine are gaining favor for Christmas trees. The brisk market for small products can be expected to continue. The spruce-fir, lodgepole pine, and aspen forests of the central Rockies will be expected to contribute substantially to the national supply of these products.

Most of the high-altitude forest land is more valuable to the economy of the region for the water it yields than for its timber products. Situated as it is on the higher slopes, the spruce-fir, lodgepole pine, and aspen forests are estimated to produce 85 percent of the total water supply for the semi-arid lands encompassing the Rockies. It is estimated that more than 4.5 million people are dependent on the water originating in the Colorado mountains.

Because of rising population and increasing industrial demands, current supplies of water do not equal demand. The high water-yielding

Figure 8.--Beetle-killed Engelmann spruce,
White River National Forest.

Figure 9.--Beetle-killed Engelmann spruce pulpwood reload at Dotsero, Colorado.

areas of the Rockies will be looked to not only to maintain present water supplies, but to increase them.

Recreation must not be overlooked. Aside from the value of the timber and water resources, the subalpine forest types provide recreation. (Fig. 10) Forests provide camping, picnicking, and hunting, besides simple esthetic enjoyment. Lakes and streams provide fishing, boating, and swimming. During the winter seasons, the abundance of snow provides skiing for many thousands of persons. These activities are not yet in serious conflict with timber and water uses, but good planning will be required to avoid it in the future.

PAST WORK

To understand and manage the forests of the subalpine zone requires knowledge of both a basic and practical nature. Considerable work has been done in all three major forest types, but much detail needs to be filled in to satisfy the wants of more intensive forestry. More work has been done on lodgepole pine silviculture and management than for spruce-fir. Similarly, while little has been done here to discover the secrets of perpetuation and improvement of aspen, more knowledge is available for this hardwood than for spruce-fir. However, we are not at the genesis of Engelmann spruce-subalpine fir forest research. We have many observations and a limited amount of research gleaned from several decades of work in and with the type, but until the advent of recent wood and pulp demands and spectacular insect depredations, little formalized research has been completed.

Figure 10.--Forests provide recreation.
Arapaho National Forest.

Management techniques that have been developed for spruce-fir and lodgepole pine have been fitted within the dictates of logging method limitations. Few silvicultural techniques have been developed that have as one of their requirements a manner or system of harvesting. Until forestry becomes much more intensive, perhaps such requirements are unnecessary. Horse logging (Fig. 11), which is inherently more compatible with silvicultural requirements than more modern logging methods, is still used. However, tractors with sulkies (Fig. 12) are being used on many sales, and cable systems (Fig. 13) of logging are employed successfully under some conditions. New logging methods are making it possible to log in stands on sites that may be so different as to require a modification of silvicultural principals developed on less inaccessible sites.

Silviculture

Silvical Characteristics

Spruce and fir generally grow together. Spruce usually makes up 70-90 percent of the volume of old-growth spruce-fir stands. Where mixtures include lodgepole pine, the natural succession is a gradual replacement of the pine. All three species are slow-growing. Spruce and fir both respond quickly to release. When young pine is released at an early age, it responds well. At older ages, degree of growth response to release is correlated with crown size and vigor. Because of the dense growth habits, all three species are generally shallow rooted and subject to windthrow when suddenly exposed to wind. (Fig. 14)

Figure 11.--Horse skidding. White River National Forest.

Figure 12.--Skidding short logs with TD-5 crawler tractor and homemade sulky. White River National Forest (Beetle-killed spruce).

Figure 13.--Overhead cable logging on Fraser Experimental Forest.

Figure 14.--Windthrown lodgepole pine. Engelmann spruce and subalpine fir are similarly shallow rooted.

While old-growth spruce forests are very susceptible to epidemic attacks by the spruce-bark beetle, it is not affected much by browsing animals or porcupines. The browsing of lodgepole pine is not a problem in closed forests, but reproduction is damaged in cutover stands. Porcupines severely damage pine in some areas. The most common diseases of spruce and fir are caused by fungi that rot roots, butts, and trunks. Spruce is also attacked by a rust that causes brooming and top die-back in the crowns. Because spruce, fir, and lodgepole pine have thin bark, they are susceptible to damage or destruction by fire.

Lodgepole pine is subject to rots, stem rust, and dwarfmistletoe. Dwarfmistletoe reduces tree vigor and also may result in death. No studies have been made to learn how to control the pest through harvest cuttings, but indications are that complete clearcutting is necessary where stands are heavily infected. Cleanup measures would vary according to stand and infection conditions.

Natural Reproduction Requirements

Some general knowledge of cone maturity and seed viability has been established for Engelmann spruce, subalpine fir, and lodgepole pine. Currently, local studies of spruce-fir seed quality and quantity and dissemination distances are being made. Requirements for seedling establishment in the mountain spruce-fir type (spruce-fir-shrub association) on moderate slopes have been tested. Spruce

germination is good on mineral, burned, and rotten-wood seedbeds (Fig. 15), but not on duff or humus. Spruce survival is favored where seedlings are protected. (Fig. 16) On severe sites, such as burns, seedlings become established only in protected spots near stumps and down-trees. (Fig. 17)

Lodgepole pine is intolerant of shade and subalpine fir is more tolerant than Engelmann spruce. It is not uncommon to have a dense overstory predominately of spruce and an understory of primarily young fir. Complete- to half-shade favors fir over spruce and full sunlight to 60-percent shade is more favorable to lodgepole pine and spruce seedlings than to fir seedlings. Results from studies and observations in the central Rockies and other lodgepole pine regions have demonstrated that seedling establishment is seldom a problem in lodgepole pine. Regardless of type of harvest cutting and slash disposal, lodgepole pine regenerates abundantly on most areas. (Fig. 18) Usually lodgepole pine also regenerates well following fires. (Fig. 19)

Artificial Regeneration

Generally, the same site requirements are necessary for artificial regeneration as for natural regendration. Trials have shown that 3-1 spruce and 2-1 lodgepole pine transplant stock survived better than younger nursery stock. Planting should be done in the spring while young trees are still dormant. Sites having loose-textured soils should be selected for planting over areas with heavy soils. Planting sites in aspen or in dead timber are best because transplants are protected from direct sunlight and drying winds.

Figure 15.--Well decayed logs form a good seedbed for Engelmann spruce seedlings.

Figure 16.--Spruce-fir reproduction under partial stand of subalpine fir and beetle-killed spruce. White River National Forest.

Figure 17.--Establishment of spruce reproduction in protected spots near stumps and down-trees on old burn. Pike National Forest.

Figure 18.--Lodgepole pine regeneration after clearcutting in strips. Fraser Experimental Forest.

Figure 19.--Lodgepole pine coming in after the Jim Creek fire. Arapaho National Forest.

Currently, planting and seeding in beetle-killed spruce has not been very successful. Germination has been good, but survival poor.

Management

Growth and Yield

Results show that spruce-fir will yield 150-300 board-feet per acre annually, depending upon age, density, and vigor of stand. Average volumes per acre vary from practically nothing at timber line, to 40,000 or more board-feet on good sites.

Lodgepole pine yields are not as great as those for spruce-fir. Studies showed that annual yields to 150 board-feet per acre can be expected. Volumes per acre will vary from as little as 1,500 board-feet to as high as 25,000 board-feet, per acre, depending upon site and competition. Twelve-fifteen thousand board-feet per acre are good for old-growth stands (Fig. 20) on average sites.

Site index curves have been constructed for selectively cut spruce-fir, but they have not been widely used. No site index data are available for virgin stands. Specific site indices are not available for lodgepole pine.

Stand Improvement

Thinning and pruning studies have not been adequate to produce much information. Because spruce-fir regeneration usually is not overly dense to the point of stagnation, thinning is not urgent in a young stand. Improvement cuttings in cutover stands benefit a residual stand in eliminating diseased and poorly-formed or damaged trees. On

Figure 20.--Old-growth lodgepole pine.
Fraser Experimental Forest.

the other hand, thinning in overdense lodgepole pine stands has demonstrated that relatively heavy, single-tree and crop-tree thinnings release young pine. Because of lodgepole pine's inability to respond to release when it is 75- or more-years old, release cutting should not be attempted. Pre-commercial thinnings should be confined to stands 40-years old or less.

Little pruning information is available for spruce and lodgepole pine. In limited field pruning trials of spruce, epicormic branching developed following pruning of live branches. Because lodgepole pine's rotational size is so small, it is questionable if pruning for quality alone is worth while. No formal research has been done to determine the physical and/or economical feasibility of pruning.

Harvesting Methods and Protection

Probably more formal research has been done in the testing of harvest methods than in any other phase of spruce-fir-lodgepole pine management. For both forest types, clearcutting is recommended for harvesting old-growth forests. Experimental partial cutting has not been successful for spruce-fir or lodgepole pine forests. Wind losses, especially in selectively cut, over-mature stands of spruce-fir, have nearly always been excessive. Partial cutting in lodgepole pine has usually resulted in excessive blowdown losses. (Fig. 21) Also, because most lodgepole pine does not respond well to release, residual stands grow slowly despite low mortality.

Figure 21.--Lodgepole pine blow-down following heavy selection cutting. Fraser Experimental Forest.

For spruce-fir individual tree selection or two-cut shelterwood (Fig. 22) and group selection (Fig. 23) have been tested on the Fraser Experimental Forest. Up to 60 percent of the total volume was removed in both cuttings.

In an 11-year period following individual tree selection, wind losses averaged 60 board-feet per acre per year, leaving only an annual net growth of 43 board-feet. Heavy selection cutting is not recommended where a residual growing stand is to be retained for future harvests.

Group selection gave only 46 board-feet per acre per year. Wind losses were not as great as for the individual tree selection, but potential growth of residual stand, in effect, was reduced because release was sacrificed for a decrease in wind mortality. Group selection should not be used until the old-growth spruce-fir is brought under management.

Strip clearcutting (Fig. 24) of spruce-fir is recommended where advanced reproduction is insufficient and successful regeneration is dependent upon an outside seed source. Width of strip is dependent upon stand condition and susceptibility to wind-fall. Overmature, dense stands are subject to windfall and clearcutting should be confined to narrow strips. Wider strips, modified by local topography to control wind losses, can be used for clearcutting more vigorous stands.

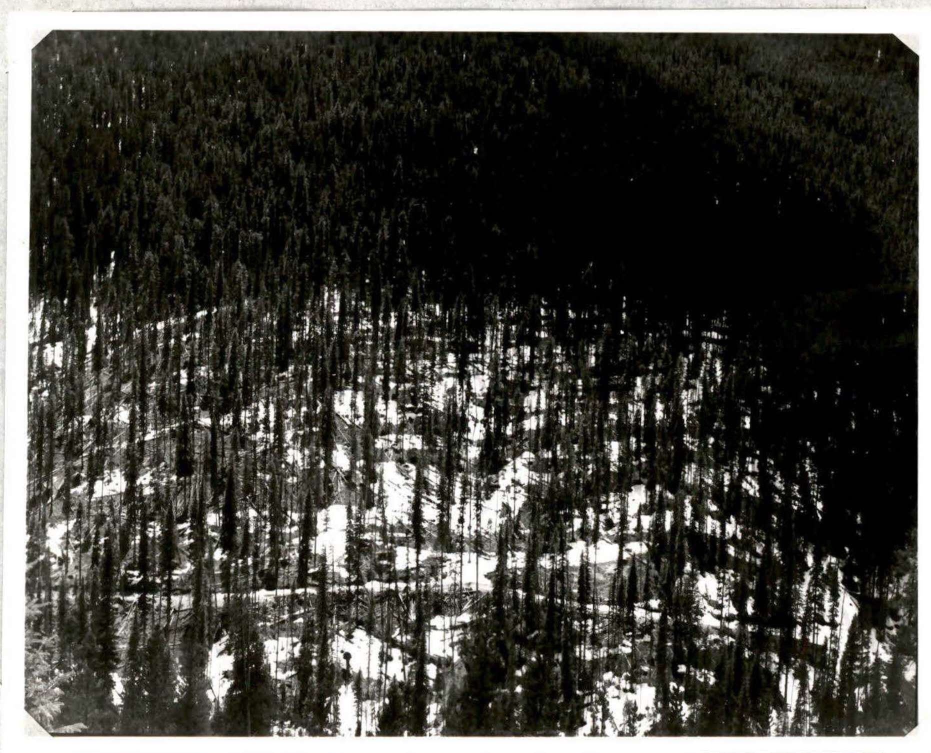

Figure 22.--Harvesting spruce-fir by two-cut shelterwood. Fraser Experimental Forest.

Figure 23.--Harvesting spruce-fir by group selection. Fraser Experimental Forest.

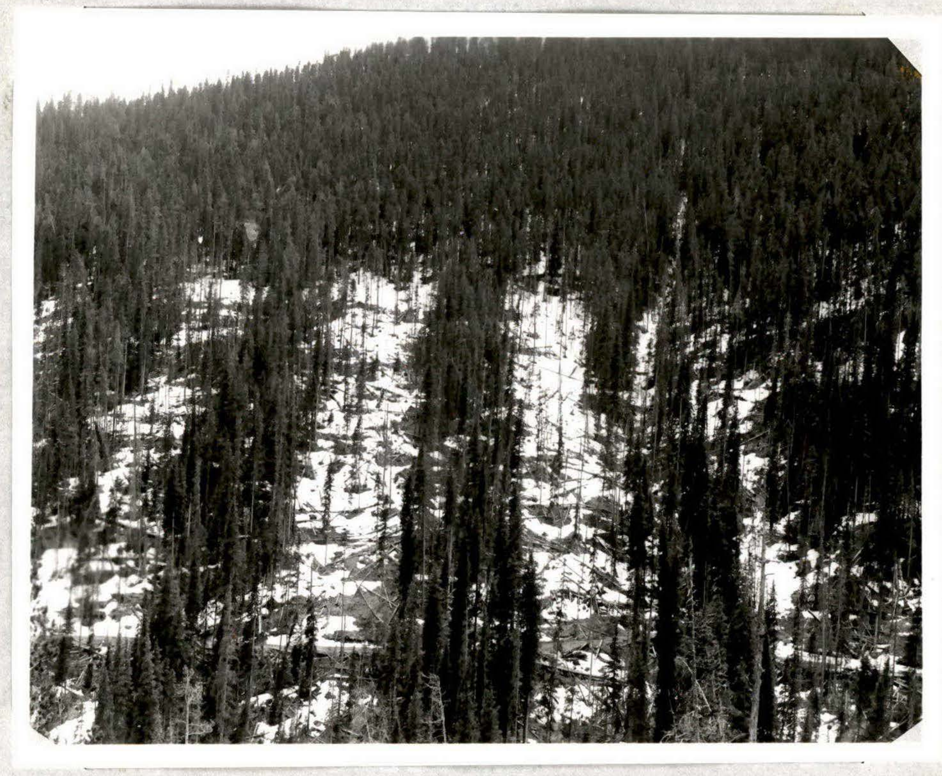

Figure 24.--Harvesting spruce-fir by vertical strip clearcutting. Fraser Experimental Forest.

Block or patch clearcutting is best adapted to decadent, overmature spruce-fir forests having considerable advanced reproduction. (Fig. 25) However, the size of the blocks should not be so large as to prevent seeding from contingent, uncut stands. Where old-growth stands are subject to epidemic attack of bark beetles, larger clearcut blocks may be justified.

Slash Disposal

Slash concentrations are usually heavier after spruce-fir harvesting than following lodgepole pine cutting. Usually, slash disposal to reduce fire hazard in cutover spruce-fir or pine is not necessary. Lopping and scattering of lodgepole pine slash is considered more desirable than burning. Not only is the seed distributed more uniformly over the area, but the slash offers mechanical hinderance that tends to control excessive reproduction. Burning of slash should be done only around camp and mill sites and along roads.

Mensuration

Only limited work has been done in the field of forest measurements. Board-foot volume tables have been constructed for virgin and cutover spruce-fir and lodgepole pine. In addition, cubic foot and pole tables have been developed for lodgepole pine. Local volume tables for both forest types have been devised by National Forest personnel.

Figure 25.--Clearcutting of overmature spruce-fir, lodgepole pine. White River National Forest.

Utilization

Logging Methods

Preliminary tests and demonstrations using the Wyssen skyline crane (Fig. 26) in the central Rockies and other regions indicate real possibilities for cable logging. Operating costs are not excessive and logging can be accomplished on steep slopes with little ground disturbance. Where road networks are impossible or undesirable to build, logging can be completed using any harvesting pattern suitable to the watershed management objectives or silvicultural requirements of a forest.

Partial cutting of lodgepole pine has never been very successful in increasing growth on residual trees, but old loggers' selection cuttings show the possibilities of partial overstory for control of overdense regeneration. Generally, when at least 6,000 board-feet to the acre were left and the site was protected, windthrow was not excessive. Blow-down losses were great in stands containing lesser volumes.

However, even-aged management seems to be best adapted to the silvical characteristics of lodgepole pine. Clearcutting usually creates conditions desirable for regeneration and at the same time reduces wind losses. For most sites, with thrifty, even-aged or broad-aged stands, vertical or horizontal clearcut strips laid out perpendicular to the direction of windstorms is recommended. Where a lodgepole pine forest is decadent and over-mature, mistletoe-infected, or multiple-aged in even-aged groups, clearcutting in patches or blocks is best silviculturally. The size, shape, and arrangement of clearcuts should be governed by condition of stand, wind exposure, and logging requirements.

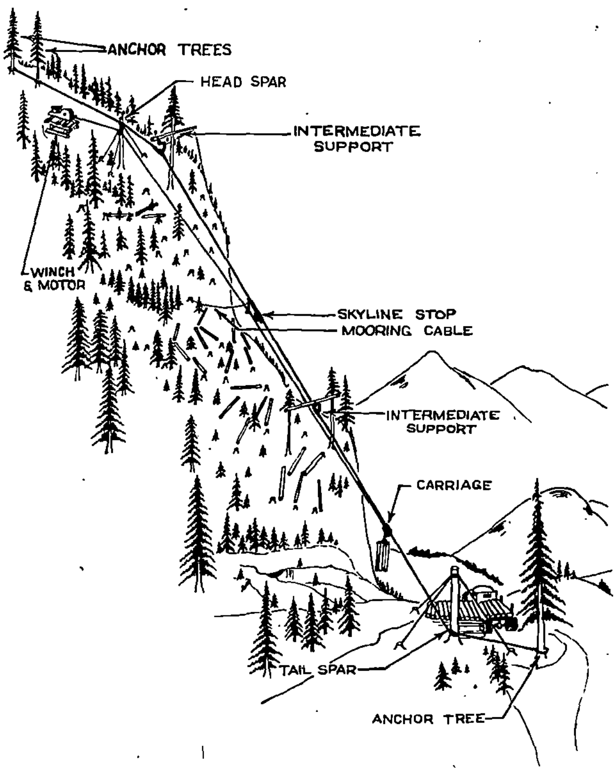

Figure 26.--Schematic diagram of Wyssen overhead logging system.

In all methods of cutting, windfall hazard must receive special consideration. Wind cannot be kept out of stand, so its effect must be reduced. Many of the basic factors influencing windfall are understood. It remains to adapt general concepts of wind behavior as influenced by topography to specific stand characteristics.

PROBLEMS

Engelmann Spruce-Subalpine Fir

Spruce-fir forests contain the largest volumes and acreage of potential timber in the central Rocky Mountains. They are also the most inaccessible and costly to log. As a result, most of the forests have been relatively untouched by logging. The overall problems in spruce-fir management are, therefore, associated with (1) the conversion, through harvesting, of the old growth before wind, insects, and disease destroy the stands (Fig. 27); (2) securing quality stand replacement after cutting; and (3) the artificial rehabilitation of insect-killed stands.

Not all of the spruce-fir is decadent and where such stands are intermingled with vigorous mature stands, the old growth should be cut first. Removal will not only salvage timber that will otherwise be lost, but will remove the centers of insect infestations which continue to cause periodic spruce-beetle outbreaks.

There are eight Forest Management and Utilization problems in the spruce-fir type that require research effort by personnel assigned to the Fort Collins Unit.

(1) Site index - site quality

Basic to the management and silviculture of any species is a knowledge of site capability. Only through recognition of differences in site

Figure 27.--A decadent old-growth Engelmann spruce-subalpine fir forest, Arapaho National Forest.

productivity can specific management objectives and the silvicultural procedures necessary to attain these objectives be determined.

Site indices, based on height overage, are available for selectively cut stands. However, they have not been widely used. No indices are available for uncut stands. Broad stand condition classifications have been made, based upon site-soil, stand, and age conditions. But these are too general to be of any real value in site classification.

Suitable height overage site indices are needed for mature stands. The broad stand condition classification needs to be re-evaluated.

Determination of conventional site indices for reproduction stands and for insect-killed areas in need of reforestation are not possible. Many high-priority problems exist under these conditions and work cannot be effective until site quality is defined. Information on the effects of soil and other site factors are needed to evaluate site quality. Knowledge of the effects of soil moisture, temperature, and texture are a necessary basis for successful plantation establishment.

(2) <u>Harvesting inaccessible stands</u>

Throughout the area of spruce-fir forests there are many stands containing merchantable size timber that are now so remote or inaccessible that they are not included in commercial timber inventories or allowable cut figures. Unless the need for controlling spruce-beetle outbreaks results in the construction of Forest Service built access roads, such areas frequently remain untapped.

The majority of these stands are located in the higher mountains where watershed values are high and topography too steep to permit the use of conventional logging methods. In view of the emphasis on increasing

water yields and timber products to meet the needs of a rapidly-expanding population, what can be done to encourage cutting and how can these difficult areas be harvested without damage to important watershed values? Through stumpage adjustments? Access road development? Improved logging methods?

The general physical and economic feasibility of the skyline-crane needs further testing under Rocky Mountain topographic and timber conditions. The watershed, silvicultural, and recreational values of less extensive logging road networks need further consideration. Adaptability of the skyline-crane to watershed management programs, beetle-control projects, and special product logging needs to be evaluated.

(3) Harvest cutting

Harvesting operations in spruce-fir are directed toward even-aged management. National Forest Administration uses clearcutting in strips, blocks, or patches for stand regeneration. The use of a silvicultural system applicable to even-aged management is a logical choice. The majority of spruce-fir forests are old growth. They originated after extensive areas were destroyed by fire and/or insects and are characteristically even-aged or even-sized. Partial cutting is not adapted to these stands as a means of arresting stand deterioration or increasing growth. In addition, clearcutting is more compatible with the larger logging equipment now being used.

There are several important aspects to be investigated in clearcutting spruce-fir. Information is needed on the size of opening and arrangement of patch, block, or strip pattern that will (1) best fit stand and site conditions; (2) provide for natural restocking; (3) effectively reduce wind losses

and subsequent spruce-beetle population buildups in adjacent standing green timber; and (4) to conform to road-building and logging requirements.

(4) Protection

Protection problems in spruce-fir are associated with wind, insects, and disease.

The most common diseases are caused by wood-rotting and rust fungi. Important rots are red ring rot (Fomes pini (Thore) Lloyd), red root and butt rot (Polyporus circinatus Fr.), brown trunk rot (Peniophora luna Romell), red heartrot (Stereum sanguinolentum A & S), brown stringy rot (Echinodontium tinctorium E. & E), shoestring rot (Armillaria mellea (Vahl.) Quel), brown cubical rot (Coniophora puteana (Fr.) Karst), white spongy root rot (Poria subacida (Pk.) Sacc.), and white pocket rot (Polystictus abietinus (Dicks.) Sacc. & Cub.). Balsam fir rust (Melampsorella cerastii (Pers.) Schroet.) and spruce broom rust (Peridermium coloradense (Diet) Arth. & Kern) are the most important rust fungi.

Research is needed to determine the economic importance of these disease organisms, their method of entry, rate of spread, and means of control. The influence of site and tree characteristics and the relationship of disease to growth and mortality need further study.

Old-growth Engelmann spruce is especially susceptible to devastating attacks by the spruce bark beetle (Dendroctonus engelmanni Hopk.). Heavy blowdown in 1939 on the White River Plateau resulted in an epidemic infestation that destroyed 5 billion board-feet of spruce before being controlled in 1952. Subalpine fir is defoliated by the spruce budworm (Choristoneura fumiferana Clem.), and the western balsam bark beetle (Dryocoetes confusus Sw.) is at times very destructive.

Information is needed to determine the means by which future spruce-beetle population buildups can be prevented, detected, and controlled. Research is needed on the influence of tree characteristics, harvesting methods, utilization standards, climatic, and biotic factors on insect populations. Other forest insects indigenous to spruce-fir forests and their potential importance need further study.

Information is needed on wind behavior in relation to land forms. Regardless of the pattern and size of clearcut, there seems to be more blowdown in some stands than in others. The types of stands and kinds of situations where blowdown is most likely to occur must be determined so that stands of high windfall risk can be recognized. The variables of wind direction, type of cutting, topographic position, slope exposure, direction of cutting boundaries with respect to wind direction, size and shape of cutover areas, length of time since cutting, stand condition, soil depth and drainage, wood decay, tree size, and crown class must be studied before any specific recommendations can be made to reduce post-logging windfall losses.

(5) Natural reproduction

Evidence of how well Engelmann spruce reproduces after cutting is not conclusive. A small scale study of harvesting methods on the Fraser Experimental Forest has shown sufficient advanced reproduction existed after cutting to adequately restock the cutover areas, but it was predominantly subalpine fir. Five years later, the amount of advanced reproduction destroyed by logging had been replaced, largely with subsequent spruce reproduction. Observations on the national forests of Colorado have indicated that spruce and fir reproduction is difficult to obtain

under some conditions. However, no quantitative measurements have been made to verify these observations.

The question of spruce reproduction involves three interrelated functions: (1) seed production and dissemination, (2) germination, and (3) establishment and early survival. The relative importance of the factors influencing these must be determined before we can answer the question of how, through harvesting methods, can adequate spruce and fir regeneration be obtained when and where it is wanted.

Do we fail to get reproduction in some areas because of an inadequate seed supply? Information is needed on the effect of age, tree vigor, site, and stand density on seed production and viability. The number of viable seeds produced in a seed year, per cone, per tree, or per acre, and the frequency of seed years is not known. The distance of effective seed dispersal is not known. Information is needed on the influence of tree height and the effect of mountainous terrain on air currents to make most effective use of natural seedfall.

Are poor seedbed conditions responsible for regeneration failures in some areas? Type of seedbed influences seed germination through its effect on soil moisture and temperature, but seed will germinate on almost any media providing the fundamental factors necessary for germination are present. Spruce and fir are known to germinate well under a variety of conditions, but there is no information available on the optimum or minimum conditions required for germination. The influence of light intensity, soil acidity, temperature, moisture, seed characteristics, seed enemies, and competing vegetation needs study.

The factors that are responsible for most seedling mortality may be grouped under four causes: (1) moisture, (2) temperature, (3) light intensity, and (4) mechanical and biotic injury. Information is needed on (1) the influence of differences in seedbeds, competing vegetation, soil texture, and topographic variations on moisture, temperature, and light; (2) the stage of development when danger of lethal heat injury is greatest and the temperatures and durations required to produce heat injury; (3) the period of time the soil root zone can be devoid of available moisture before death from drought occurs; (4) the air temperatures and durations at which frost injury occurs; (5) the effect of different intensities of light and shade; and (6) the biotic agents associated with natural reproduction losses. Other closely related questions of how old is a seedling before it is established and what constitutes sufficient stocking at time of seedling establishment need answers.

(6) Artificial regeneration - beetle-killed stands

Planting and seeding in the spruce-fir type is limited almost entirely to reclamation of insect-killed areas. There are many thousands of acres of beetle-killed national-forest land in Colorado in need of some artificial regeneration.

Administrative seeding and planting studies using spruce and lodgepole pine have been unsuccessful. Seed will germinate in seed spots but will not survive the first winter. Losses appear to be associated with spring frost heaving. Stock planted in the spring, using a modified deep hole method, usually survives the first growing season, but losses begin to occur during the first winter and continue as time since planting increases.

A number of reasons have been advanced to explain these plantation failures; source and age of planting stock, handling and planting methods, and climatic and biotic factors. These are based on observations and not the results of any measurements.

The failure of planted stock and seedlings to survive is one of the high-priority research jobs in spruce-fir management. Information is needed on the effects of summer and fall drought, insolation, frost heaving, temperature, and differences in seedbed and soil texture as related to survival. Seedbed and seed spot preparation, methods of planting and handling stock, size and age of planting stock, and season of planting and seeding require study. No information is available on the effects of changes in site quality and competing vegetation, rodents, soil nutrients, soil mycorrhizae, and seedling insects and diseases. The use of subalpine fir in planting must be investigated.

(7) Stand improvement

Cutover stands of old-growth spruce-fir are usually in need of improvement cutting. The residual understory and overstory contain many damaged, defective, and deformed trees. These waste growing space that should be used by reproduction and healthy, young trees in the replacement stand. Through removal of the undesirable trees in stand improvement, growth is concentrated on the better stems. We need to know how to improve growth and quality through stand improvement. At present little is known about the selection of future timber trees from the post-logging residual stand.

Information is needed on the type, size, and location of injuries that are most likely to result in defect or disease during the life of a

tree and their rate of spread. More information is needed for the detection of internal defect from external indicators. The possibilities of pruning spruce and fir for quality improvement, the response of spruce and fir to thinning, and the optimum density for quantity-quality increment for a specific end product need investigation.

(3) Defect indicators

Decay and other defects in trees constitute a perplexing problem in the determination of merchantable timber volume. Inaccuracy in net volume estimation is perhaps the greatest disadvantage to the practice of selling stumpage. Timber is customarily sold on the basis of net volume. This is standard practice and is universally accepted by the timber industry. When trees are felled and cut into logs, the scaler can usually observe and measure defects and then make the proper deduction from gross scale. Determination of defect in standing trees is a somewhat more complex problem.

At the present time there is a trend toward the sale of timber by tree measurement rather than by log scale, but the success of the tree measurement method depends upon : (1) a satisfactory estimate of gross volume, and (2) an accurate estimate of cull. It is apparent then that much depends on the ability to detect and estimate defect in standing trees.

Hornibrook made a comprehensive study of the external indicators associated with defect in standing spruce, fir, and lodgepole pine. He found that most internal defect was indicated by the presence of conks and swollen knots, cankers, fire scars, forks, branch stubs, lightning scars, top injuries, spike tops, frost and wind cracks. In addition, the amount of deduction in net volume associated with these indicators could be

predicted with reasonable accuracy. Further field testing of this study and a re-evaluation of decay in spruce-fir-lodgepole pine is needed. Information is also needed to determine cull in cut logs from external indicators.

Lodgepole Pine

Lodgepole pine forests are second to spruce-fir in volume and acreage in the central Rocky Mountains. Lodgepole pine is mostly found in uncut stands; but because of repeated past fires, there are extensive areas of young growth. The primary problems in lodgepole pine management are, therefore, associated with (1) old-growth conversion and (2) young-growth management. Management is complicated by the presence of dwarfmistletoe infection in most stands.

Even though more is known about the management and silviculture of lodgepole pine than spruce-fir, there is need for much additional knowledge. Five problems that require research by the Forest Management and Utilization personnel of the Fort Collins Unit have become apparent during recent years.

(1) Optimum level of growing stock

Lodgepole pine frequently reproduces overabundantly following clearcutting or fire. Intensive competition for growing space does not permit good development in such dense stands. Although shade-intolerant, lodgepole pine does not thin well naturally. Severe crowding of young trees of the same size leads to retarded diameter and height growth. Even when crown classes are well differentiated, too many trees persist. Artificial thinning is needed under such conditions.

Dense stands do not make full use of the capability of the site to produce trees of merchantable size within a reasonable period of time, although very dense stands may be desirable during early life. Total growth in a dense stand may exceed that of a thinned stand. However, volume in the thinned stand is concentrated on stems that will produce a usable product.

Commercial operations are not now possible in most stands in need of thinning. This problem will be minimized by the development of markets for posts, poles, pulpwood, and other small round products. Recommendations for thinning practices must be developed now so the information is available when needed.

Few recommendations are available for guidance in thinning lodgepole pine in Colorado and Wyoming. Results from plots on the Arapaho, Medicine Bow, Bighorn, and Shoshone National Forests established between 1924 and 1934 indicate levels of stocking for precommercial thinnings of (1) 600 trees per acre in stands averaging 1-2 inches d.b.h., (2) 500 trees per acre in stands averaging 3 inches d.b.h., (3) 400 trees per acre in stands averaging 4 inches d.b.h., and (4) 300 stems per acre in stands averaging 5 inches d.b.h.

Additional information is needed to determine reserve stocking for all combinations of age, size, stand and site conditions. A study must determine how to thin stands that are now at least 30 to 40 years old. Guidelines are needed to determine proper stocking of stands from the time of their beginning to the end of the rotation so that the best quality-quantity increment for a specific end product is obtained. Perhaps greater spacing is desirable if sawlogs and poles rather than fiber is the end

product. Maybe both sawlogs and pulpwood can be grown - pulpwood to be taken out in intermediate cuts and sawlogs at rotation. Little information is available on the methods of thinning - even less is known about pruning.

Cubic volume tables giving volumes by diameter and total height will be needed to analyze the results of thinning studies. These volume tables will be prepared during studies for which they are needed.

(2) Site index-site quality

Knowledge of site capability is a necessary prerequisite to the intensive management of lodgepole pine. Although much work has been done on the silvicultural characteristics of lodgepole pine, no studies of the effects of site factors on the growth of lodgepole pine have been made in the central Rocky Mountains. Site indices have been made for selectively cut stands. However, they have not been used because the relationship of total height to age did not follow the usual trend. The heights of dominant trees in partially cut stands apparently did not adequately represent the heights of the dominant trees in uncut stands.

Quantitative measurements of site quality (soil depth and texture, slope exposure and steepness, precipitation, etc.) as it effects soil moisture are needed. Suitable height average site indices are needed for mature stands.

The determination of site index by height-age curves is not possible in young stands or burned-over areas. These are areas where many high-priority research problems exist. In order to determine management objectives and silvicultural procedures, site conditions must be evaluated.

(3) Control of dwarfmistletoe

Dwarfmistletoe (*Arceuthobium americanum* Nutt) is the worst recognized disease enemy of lodgepole pine in the central Rocky Mountains. Recent surveys have shown that more than one-half of the commercial lodgepole pine in Colorado and Wyoming is infected to some degree. The surveys also indicate that in merchantable stands dwarfmistletoe is responsible for a marked reduction in growth, increased defect and degrade and heavy volume losses resulting from the ultimate death of many trees. Dwarfmistletoe is most damaging in partially burned or cut stands and of least consequence on regenerated burns following holocaustic fires; damage to uncut stands is intermediate.

Since partial cutting in dwarfmistletoe infected stands creates ideal conditions for maximum damage, it should be avoided. Silviculturally, lodgepole pine responds best to some form of clearcutting. It also appears to be the best way to control dwarfmistletoe. However, unless all infected residual trees are cut, girdled, or poisoned at the time of logging, the sanitation value of clearcutting is voided. Any infected residual trees left alive will reinfect incoming reproduction and lead to the development of new infection centers.

Even where stands are properly clearcut, some dwarfmistletoe will develop in the regenerated stand bordering infected areas in the uncut strips or blocks. However, if it is possible to cut the residual areas within 20 to 30 years, damage to the initial replacement stand will be slight.

Initial work on dwarfmistletoe control will be confined to recently clearcut and newly regenerated stands. One group of studies is needed to

provide additional information on the influence of site, stand, and tree characteristics, and age on the intensity of infection and the rate of spread. The effect of size and shape of clearcut area on rate of spread and intensity of infection need study.

Information on the control of dwarfmistletoe through stand improvement, thinning, and pruning is lacking. Because of the interval between seed germination and appearance of the first shoots, it is virtually impossible to see and destroy all infection in one operation. The intensity number and frequency of followup treatments in regeneration stands must be worked out. The role of fire in the control and spread of dwarfmistletoe must be examined. Information is needed on the influence of climatic factors on the degree of infection. The degree of dwarfmistletoe infection below which control is not necessary must be determined.

(h) Treatment of slash

National Forest Administration in Region 2 considers the treatment of logging slash as it effects (1) establishment of natural regeneration, (2) elimination of dwarfmistletoe, and (3) reduction of fire hazard, a high-priority problem in the management of lodgepole pine.

Whether slash treatment is beneficial or necessary to the establishment of lodgepole pine regeneration is open to question. A study on the Fraser Experimental Forest has indicated that lopping and scattering is preferred to piling and burning as a method of slash disposal because the density of the replacement stand is more nearly optimum. Lopping and scattering apparently resulted in a more even distribution of seed over the cutting area and slash offered mechanical interference that tended to reduce

the number of surviving seedlings. In the northern Rocky Mountains, Roe found areas where slash was lopped or untreated and/or the soil was scarified restocked to overdense stands, while areas where slash was actually burned were understocked. Burning had apparently destroyed much of the seed.

Initially a study is needed to determine the effect of different kinds and concentrations of untreated slash on the establishment of lodgepole pine regeneration. Amount of logging slash on the ground affects seedlings establishment and survival by creating mechanical hinderances and through its influence on moisture and temperature. Period of time slash has been on the ground may also influence seedling establishment.

The relationship between seed supply, slash-disposal methods, (windrowing and burning, windrowing, piling and burning, lopping and scattering, etc.), and cutting to seedling establishment must be evaluated on specific seedbeds and under specific site-soil conditions.

In order for treatment of slash to effectively reduce or eliminate dwarfmistletoe from infected stands, fire must be used. The fire must be a complete burn that destroys not only the slash but also the standing infected residual trees. Under normal conditions, such a complete burn is seldom possible nor is it usually desirable from a fire-control standpoint. The effectiveness of slash-disposal through burning alone as a dwarfmistletoe control measure is, therefore, doubtful. However, the use of fire in conjunction with stand improvement work as a method of disposing of slash and destroying dwarfmistletoe infected trees should be investigated.

A method for evaluating the resistance to control and rate of spread of fire in lodgepole slash fuels is needed in order to assign classes of

potential fire hazard to different kinds and concentration of slash. Information on the length of time after cutting that the initial level of hazard is maintained is also needed. The effectiveness of different methods and intensities of slash-disposal on hazard reduction must be evaluated.

(5) Natural regeneration on south slopes

On north and east facing slopes, lodgepole pine grows in both pure stands and in mixed stands with Engelmann spruce and subalpine fir. Under these conditions lodgepole pine is considered to be the subclimax or a serial stage of succession. On south slopes, at higher elevations, lodgepole pine is usually found growing in pure stands and is considered here a climax species.

It has been demonstrated that lodgepole pine will reproduce satisfactorily after partial cutting on other than south slopes, but windfall losses are usually so high and growth of the residual stand so slow that net increment is negligible. These results have led in part to the recommendation that some pattern of clearcutting, under which regeneration is adequate and the high risk windfall trees are removed, be used to harvest old-growth lodgepole pine on these slopes.

However, a large proportion of uncut lodgepole pine is growing on warm slopes. Besides being more inaccessible than previously cut areas, stand density is poorer than in bottomland areas and lower slopes. On south slopes, regeneration has been either difficult to obtain or the distribution poor, especially when the stands have been clearcut. Much of the regeneration difficulty has been seedling mortality caused by exposure to high temperatures and subsequent drying out of the upper layers of soil.

This condition suggests that some type of partial canopy may be beneficial to regeneration on south slopes. It is possible that sparsely stocked warm-slope lodgepole pine stands are more windfirm than high density stands.

The possibility of using a modified two-step shelterwood system of cutting to manage this particular forest condition should be investigated. The effect of different intensities of light (canopy shade), soil textures, and seedbeds on soil surface temperatures and soil moisture need study. Information is needed on the occurrence and duration of lethal soil surface temperatures and soil moisture available during the growing season. The length of time overstory shade is needed to protect seedlings from heat and drought losses and the influence of slash and understory regeneration on seedling establishment are not known.

Aspen

Aspen in the central Rocky Mountain region is less extensive and important than either spruce-fir or lodgepole pine forests, but does constitute an important resource. Demand is only now permitting exploitation in aspen stands. The major problems are, therefore, associated with (1) old-growth conversion and (2) integration of uses.

Although aspen has been studied intensively in the Lake States and Canada, so little has been done in the Rocky Mountains that we do not know to what extent practices developed elsewhere are applicable. As a first step in that direction, an aspen management task force, including representatives from Lake States and Intermountain Regions, was organized by the Station and Region 2. Following an extensive field trip through the aspen forests of western Colorado and a comprehensive review of literature, the task force developed an interim guide to the management of aspen.

These guidelines summarized the known information on aspen silvics, site quality and rotation, stand conditions and damaging agents that is applicable to Colorado. Management objectives based on this information were set up and the cutting and cultural practices necessary to attain the objectives were outlined. The interim guidelines are intended as a stop-gap measure until more specific information is available. However, the problems that will require immediate attention cannot be defined until the guidelines have been put into use and the limitations become known. Undoubtedly additional information will be needed on harvest cutting, natural reproduction, protection, site evaluation (identification of sites where aspen should be managed), methods of converting aspen to conifers where that is desirable, cultural practices, and growth, yield, and volume determinations.

OBJECTIVES OF PROGRAM

The objectives of forest management research are two-fold. One is to furnish land management agencies with the working knowledge needed to convert unmanaged stands to managed, and secondly to provide knowledge for understanding the whole biology of desirable species.

The immediate objective is to provide answers to the previously discussed problems. These problems are those that presently or imminently are troubling land managers; however, popular interest should not be allowed to entirely divert research efforts. To obtain a usable, dynamic fund of knowledge, a research program needs careful thought and planning. Each segment of research in forest management and silviculture should provide prerequisite information for future studies, as well as satisfying

immediate demands. There should be no waste nor should there be any reason to regress to obtain bypassed information.

The ultimate objective of forest management research in the spruce-fir, lodgepole pine, and aspen zone is to learn how to manage these species so that the lands upon which they are growing will produce the greatest overall return. These forests should be managed so that public demands for water, timber, and recreation will be satisfied to the fullest extent possible. Solutions to silvicultural and management problems must be obtained with a view to the likely superior demands for water and important requirements of recreation.

As human populations increase, some degree of land use capability zonation, either purposefully or consequentially, will materialize. No single land use will be considered uniformly of paramount importance on each and every acre throughout the subalpine zone. Therefore, the information to be obtained through research must be sufficient to enable flexibility in land-management methods. Solutions to forestry problems should encompass the three forest types of the zone and the representative range of slopes, aspects, soil depths, and types. In addition, findings should be of sufficient detail to allow intelligent adjustment in accordance with any major land use.

<u>SPECIFIC STUDIES</u> (*long-term studies)

I. <u>Forest Management</u>

A. <u>Mensuration</u>

1. Growth and Yield-Site Index - Site Quality

a. Spruce-fir, lodgepole pine, and aspen

Objective.--To develop a suitable site index classification for mature stands of spruce-fir, lodgepole pine, and aspen.

Method.--Total height overage. Stands representing the common range of variation in age and site conditions will be selected for sampling.

b. Spruce-fir and lodgepole pine

Objective.--To determine site quality on areas where conventional site indices cannot be used.

Method.--Measure and evaluate soil and topographic factors correlated with site quality. Immature, burned-over and beetle-killed stands that represent the range of soil and topographic conditions will be sampled.

2. Growth and Yield - Optimum Growing Stock

a. Spruce-fir and lodgepole pine

Objective.--To determine effective stocking when seeding or planting and the best stand density and structure for even-aged management of lodgepole pine and spruce-fir.

Method.--Determine stand density and growth relationships in stands of various ages and densities on the common range of site conditions. Develop growing-space requirements for broad range of ages or size classes and site condition.

3. Volume Tables

a. Spruce-fir, lodgepole pine, and aspen

Objective.--To determine the suitability of existing volume tables and the need for additional volume tables.

Method.--Application of standard methods of checking volume tables using trees and stands not represented in original basic data.

B. Silviculture

1. Harvest Cutting and Protection

a. Spruce-fir and lodgepole pine

Objective.--To study the basic pattern of storm damage and determine the factors that influence blowdown in spruce-fir and lodgepole pine forests, and to develop a preliminary windfall risk classification for spruce-fir and lodgepole pine forests.

Method.--Study selected cutover spruce-fir and lodgepole pine stands, including all variations of clear and partial cutting. The number of windfalls on sample plots will be tallied and information on all factors that appear to influence wind damage will be recorded.

b. Lodgepole pine*

Objective.--To develop control methods for lodgepole pine dwarfmistletoe through harvest and improvement cuttings and slash disposal treatments.

Method.--Establishment and measurement of replicated treatments with the help of the Division of Forest Pathology.

2. Natural Regeneration

a. Spruce-fir and lodgepole pine

Objective.-- To determine the stocking of cutover spruce-fir and south slope lodgepole stands, the factors that influence the germination and establishment of spruce, fir, and lodgepole pine reproduction, and the causes of natural regeneration failures.

Method.--Study selected cutover and burned-over spruce-fir and south slope lodgepole pine stands and establish sample plots to discover the variables influencing seedling survival. Locate seed traps to study the quality, quantity, frequency, and dispersal of spruce-fir seed supply.

b. Aspen

Objective.--To become familiar with the regeneration problems of cutover commercial aspen stands in the central Rockies.

Method.--Study selected cutover aspen stands for comparisons of residual stand conditions with regeneration.

3. Intermediate Cutting-Thinning

a. Lodgepole pine

Objective.--To determine effects of different degrees of thinning on growth in young and immature even-aged stands of lodgepole pine.

Method.--Analyses of remeasurement data from plots established between 1924 and 1934 on the national forests of Colorado and Wyoming.

b. Lodgepole pine

Objective.--To determine the effects of different degrees of thinning at different ages and on different sites, on the growth, form, and vigor of overstocked stands of young lodgepole pine. (To develop an optimum stand density index for different age [size]) - site classes.

Method.--Establishment and measurement of replicated study plots.

4. Intermediate Cutting-Pruning

a. Lodgepole pine

Objective.--To determine the justification of pruning lodgepole pine.

Method.--Pruning of selected thrifty, young lodgepole pine on good sites and economic analyses of projected costs and returns.

b. Spruce-fir

Objective.--To determine if spruce can be pruned without epicormic branching and infection by disease.

Method.--Pruning of selected young spruce on good sites and under different stand-density conditions to determine effect of pruning technique or treatment on epicormic branching.

Extension of studies, if epicormic branching and infection from disease is controlled, to include economic analyses of costs and returns.

5. Intermediate Cutting - Stand Improvement

a. Spruce-fir and lodgepole pine

Objective.--To develop a stand improvement guide for cutover spruce-fir and lodgepole pine stands.

Method.--Application of different intensities and methods of stand improvement and determination of effects on the growth and condition of the residual stand. (The cooperation of the forest disease laboratory is needed to determine the relationship between defect and injury, and in development of methods to control the rate of spread of diseases.)

6. Stand Condition and Structure

a. Spruce-fir and lodgepole pine

Objective.--To determine the need for re-evaluation of preliminary stand condition and structure classifications. To determine specific physical and biological peculiarities of spruce-fir and lodgepole pine in the central Rockies. (This more or less basic approach will facilitate other studies in management and silviculture.)

Method.--Study selected stands of spruce-fir and lodgepole pine for comparisons of climate, soil, stand condition, growth, composition, and understory vegetation.

C. Artificial Regeneration

1. Planting

a. Spruce-fir and lodgepole pine

Objective.--To determine the cause and reason of planting failures on the White River Plateau. (Specifically limited, initially, to the study of fall drought and frost heaving.)

Method.--Periodic examination of survival during the growing season will be made on experimental plantings of spruce and pine. Planting stock will be dug, potted, and watered at the time of field examination.

b. Spruce-fir and lodgepole pine*

Objective.--To determine the suitability of high-altitude planting and the factors affecting planting stock survival. To develop a planting program for high-altitude spruce-fir sites and south slope lodgepole pine sites.

Method.--Randomized block field plots at different sites and locations, designed to test the isolated effects of the variables associated with planting success and failure.

2. Direct Seeding

a. Spruce-fir and lodgepole pine

Objective.--To determine the cause and time of year of direct seeding failure on the White River Plateau. (Specifically limited to the study of fall drought, degree of insolation, and frost heaving.)

Method.--Randomized block field plots. Survival as affected by treatment will be measured at periodic intervals.

b. Spruce-fir and lodgepole pine

Objective.--To determine the factors affecting the success of direct seeding, and the suitability of direct seeding as a method of artificial regeneration. To develop a direct seeding program for the common range of sites and conditions.

Method.--Randomized block field plots, designed to test the variables associated with direct seeding success and failure.

II. Forest Utilization

A. Logging Methods

a. Spruce-fir and lodgepole pine

Objective.--To improve logging methods on existing areas and to discover new methods or techniques that will permit logging of steep slope forests where road networks are either impossible or undesirable to build.

Method.--Study domestic and foreign logging methods to determine adaptation to central Rocky Mountain conditions. Equipment and techniques will be demonstrated or brought to the attention of loggers and other timber operators. The use of various logging equipment and techniques will be evaluated from economical, silvicultural, and water-yield standpoints.

B. Utilization

a. Spruce-fir and lodgepole pine

Objective.--To facilitate silviculture, control of disease, and perpetuation of genetically desirable forest stands by increasing

the demand for submerchantable material. Quick conversion to desirable managed stands is possible if profitable intermediate and sanitation cuts can be made.

Method.--Through cooperation with personnel and agencies interested in small stem utilization, develop uses for Engelmann spruce and lodgepole pine posts and poles. Successful preservative treatment for Engelmann spruce must be found and pulp and small stem markets expanded. Use of lodgepole pine for posts, poles, house logs, and vegas can be increased.

PRIORITIES

The first needs for extensive forest management are measures to assure that the land will remain productive after harvesting. Once these needs are met, attention can be devoted to increasing the quantity and quality of yields. Present knowledge is such that we cannot assure the objectives of extensive forestry for the spruce-fir and aspen types. Lodgepole pine can be managed extensively with reasonable assurance.

If the forests of the Rocky Mountains are to contribute as much to the national needs as the T.R.R. forecasts would be necessary by the years 1975 and 2000, all types will have to be managed more intensively than now.

With the above points in mind, priorities have been assigned to studies listed under SPECIFIC STUDIES. Priorities have been assigned to types, to age classes within types, and to studies by types.

On the basis of the importance of the types and the status of needed knowledge, the forest types are arranged according to needs for research as follows:

1. Spruce-fir

2. Lodgepole pine

3. Aspen

Priorities among age or stand classes within types are assigned as follows:

	Old-Growth Conversion	Young-Growth Management
Spruce-fir	1	2
Lodgepole pine	1	1
Aspen	1	2

Needed studies have been assigned priorities of 1, 2, or 3 by types. The problems are separated into two groups: (1) answers needed to meet the requirements of extensive forestry, and (2) answers needed to increase quantity and quality of yields. The first category is more urgently in need of study than the second. Studies by priorities are tabulated below:

Problem	Studies Needed: Spruce-fir	Studies Needed: Lodgepole pine	Studies Needed: Aspen	Studies in Progress: Spruce-fir	Studies in Progress: Lodgepole pine	Studies in Progress: Aspen
	- - - - priority - - - -			- - no. of studies - -		
Answers needed for <u>extensive forestry</u>						
1. Methods of logging steep slopes and unstable soils.	1	1	3	1	-	-
2. Methods of harvest cutting.	1	2	1	4	2	-
3. Natural reproduction.	1	2	1	3	-	-
4. Artificial regeneration.	1	2	-	2	-	-
5. Protection						
a. Dwarfmistletoe control.	-	1	-	-	-	-
b. Stem & root diseases.	1	1	2	-	1 1/	1 1/
c. Insect control.	1	2	2	1 1/	-	-
d. Fire.	2	2	2	-	-	-
e. Animals.	-	-	1	-	-	-
6. Slash treatment.	2	1	3	-	-	-
Answers needed to <u>increase production</u>						
1. Site evaluation.	1	1	1	-	-	-
a. Identification of sites where aspen should be managed.	-	-	1	-	-	-
2. Methods of converting aspen to conifers where desirable.	-	-	1	-	-	-
3. Levels of growing stock.	3	1	3	-	2	-
4. Pruning.	3	2	-	-	-	-
5. Improvement cutting.	1	1	3	1	-	-
6. Growth and yield.	2	2	3	-	-	-
7. Volume estimation.						
a. Volume tables.	2	2	2	-	-	-
b. Defect indicators.	1	1	2	1 1/	-	-
8. Integration of uses.	1	1	2	1	-	-

1/ By Forest Disease Research and Forest Insect Research.

COOPERATION

Increasing demands for water, wood, and recreation are pulling together the interests of various agencies, groups, and industries. Cooperation with one or more of the following is now a reality or can be expected:

1. National Forest Administration.
2. State of Colorado, State Forest Service.
3. Colorado State University, College of Forestry.
4. U. S. Department of the Interior, National Park Service.
5. U. S. Department of the Interior, Bureau of Land Management.
6. U. S. Department of the Interior, Fish and Wildlife Service.
7. Koppers Company, Inc.
8. Kremmling Timber Co.
9. Nebraska Bridge Supply and Lumber Co.
10. Other logging and milling concerns.

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